Understanding Task Grouping Strategies

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This paper's concern is with the exploration of one aspect of multitasking, namely the grouping of tasks. Our own studies reported in brief within this paper and related work suggests that groupings of tasks are both possible, desirable, and occur. These grouping are behaviours that support the creation of 'sets of tasks' by some form of commonality. This commonality may refer to the tool or transformation or to facets of context such as locations or participants. In line with the assertion that task structure is a joint reflection of how a task is represented in memory and how a task is carried out in the world this paper seeks to understand the wider ramifications of such task / subtask groupings. We outline two case studies that provide supporting evidence of task groupings. From this we extract four forms of grouping that are scoped in relations to locations, deadlines, participants and roles.

Keywords: tasks, task grouping, task knowledge structures, strategies, non-obligatory goals.

1 Introduction

It is widely accepted that changes in technology, work practices and the general socio-economic environment affect the way we plan and perform tasks. A full listing of such changes is beyond this paper's scope, but examples include: the convergence of media forms in one electronic workspace; support for specialist tasks by generalists; knowledge and service work that is less constrained by the physical environment; and advances in computer power. Overall, support, opportunity and pressure for people to 'multitask' has increased. Despite rapid advances in technology, and increasing dynamics in groups and organizations, human abilities have not changed as quickly. Our capacity to deal with multiple goals and streams of

information has not increased and we need to find ways of analysing and designing for these contexts. As is often the case in HCI, theory lags technological and other advances. Deeper insights into how people interleave elements across different tasks and contexts have not informed the array of technological support for such phenomena. Some work has moved us towards an understanding of multiple tasks [Cypher 1986; Smith et al. 1997]. However, the work is either fragmented or has failed to permeate into mainstream user / task / activity analysis methods.

This paper's concern is with the task structure implications of multiple tasks, although it is grounded in a wider investigation of multiple tasks. More specifically, its concern is with how sets of tasks are grouped in a manner that balances: the goals of the individual tasks; higher-level goals; against the resources and opportunities in the task environment. Our own studies, reported in brief in this paper, and related work [Smith et al. 1997], suggest that such groupings of tasks and subtasks are both possible, desirable, and occur. These groupings are behaviours that support the creation of a set of tasks based on some of some form of commonality. The commonality can refers facets of context, such as roles, deadlines, location and participants. Following from the assertion that task structure is a joint reflection of how the human cognitive system represents task knowledge and how the task is carried out in the world [Johnson et al. 2000], this paper explores the ramifications of such task groupings.

The paper continues in Section 2 by discussing structure in tasks and reviewing the theory driven approach to task analysis, Task Knowledge Structures (TKS). We move on to introduce the background and derivation of four candidate task grouping strategies (Section 3). Section 4 elaborates and discusses the candidate groupings in more detail and includes a discussion of factors that prevent groupings from being formed. Section 5 concerns itself with the implications of this work for Task Knowledge Structures. Section 6 concludes the paper and outlines future work.

2 Structure in Tasks: Task Knowledge Structures

There are a number of 'theories of task' ranging from the ethnographically informed GTA [van der Veer et al. 1996] to the execution duration orientation of GOMS [Card et al. 1983]. The primitives in each approach vary, but they all assume that a task has some form of analysable structure, that reoccurs across performers and instances of a task.

One approach to task analysis that has considered task structure in depth is Task Knowledge Structures (TKS) [Johnson et al. 2000]. TKS is a theory-based approach to the design of interactive systems. It draws on various knowledge elicitation techniques[1] to create a representation of task knowledge that is considered functionally equivalent to a user's task knowledge. TKS holds that goal / subgoal ordering is not random and that it reflects structuring principles [Johnson et al. 2000].

The theoretical basis of TKS draws on parsimonious evidence from theories of knowledge representation and direct empirical evidence from working with TKS. TKS theory holds that a TKS is a conceptual representation held in long-term memory

[1] The main ones used are: structured interviews, text and document analysis, observations, card sorting, and where appropriate the analyst performing the task.

and processed in working memory during task performance. As such a TKS is a reflection of two concerns. The first is how the human cognitive system represents and processes conceptual knowledge about tasks. The second is the way the task is achieved in the world, i.e. what goals are held towards the world, what opportunities exist and what constraints stand in the task's way. A TKS of a task will include information about the goals and subgoals, task-objects, actions, procedures, pre- and post-conditions strategies, the relationships between tasks and roles, as well as the centrality and representativeness of task elements[2].

In TKS theory tasks are concepts [Margolis & Laurence 1999] comprised of related components of knowledge. The relationships between the task components dictates how a task is structured, understood, organized and executed. The relationships include sharing of attributes, features or functions (thus making them similar in some way), part-whole and class-instance, relationships. These relationships are not assumed to be absolute and in most cases reflect the opportunities and constraints in the environment [Medin et al. 1997].

Theoretical and empirical work developed two task-structuring principles which provide strong empirical evidence for structure in tasks. The *categorical structuring* principle dictates that those task components that are semantically related are grouped together. This then results in a grouping of actions on those components. The *procedural dependency* principle dictates the enabling, priming, temporal and cause-effect relationships between task activities that give rise to procedural dependencies. Evidence for these principles is most manifest in the work on the PRIDE project. Experimentation provided strong supporting evidence that users will impose their own task model upon interfaces that partially or fully fail to reflect that task structure. With a badly structured interface, errors and slower task execution are partly due to the need to translate the TKS of the task into an execution path. In contrast an interactive system that fully supported the TKS of a task by obeying the principles, resulted in higher measures of objective and subjective usability.

To date, research and practice with TKS has predominantly worked from a single user, single task perspective. However, TKS's concern with the structure of tasks and the increase in computer support and group and organizational pressure for multitasking has led to an interest in applying and extending TKS to, and in contexts where, multiple tasks are performed.

2.1 TKS and Multiple Tasks

TKS has made use of a subset of the LOTOS formalism for representing temporal relationships (e.g. serialization, choice, parallelism, interleaving, Markopoulos et al. [1997] within a task, but not the temporal relationships between a set of tasks. In contexts such as those reported in this paper and elsewhere [e.g. Cypher 1986; Johnson et al. 2001; Smith et al. 1997] as well as multiple tasks, there are multiple roles, goals, pre- and post-conditions, task-objects, tools, and participants to consider. As we move beyond the single user single task perspective we note that a person may have a set of tasks whose interrelationships are more complex than the

[2] TKS has been applied to domains such as radiography, architectural design, and flight decks and used in cooperation with a range of interactive system development methods, including scenarios, structured design, object oriented design, OMT, UML and formal specification languages.

within and between role relationships currently modelled by TKS. Even with a set of tasks that are instances of the same class (e.g. writing a document) the priorities and deadlines that lie behind a task's performance may differ, for example writing a grant application maybe more important than updating a resume. In some domains, the order of a set of tasks may be mutable, particularly in domains that are strongly shaped by intentional, social and organizational forces.

We can also see that groupings of tasks and subtasks are both possible, desirable, and occur. The groupings can be dynamically formed in relation to the environment, or more formally planned and socially constructed. Examples of the former are grouping tasks by their location or participant. Examples of the latter are meetings that group together participants and tasks. The presence of multiple tasks entails accounting for phenomena such as task switching, suspension, interruptions and in the context of this paper, the creation of groupings of tasks. Our concern is with being able to describe, analyse, model and comprehend the structure of both the individual tasks and any groupings of tasks that occur in task planning and performance.

2.2 TKS and Strategies

In TKS strategies are configurations of behaviour that people develop to cope with constraints, requirements and opportunities in their environment. An example is the strategy Hourizi & Johnson [2001] discovered in pilot to co-pilot, and pilot to air traffic control operator in flight deck systems. A design based on this strategy was shown to significantly reduce the errors in performance of specific scenarios with the automated flight controller unit.

A key part of the characterization of strategies is that although goal driven, they are non-obligatory behaviours [Bhavnani & John 1997], the goals of the specific task goals can be achieved without their use. Their use entails that decisions be made about the use of resources in the environment, that are not immediately essential to the task. Our concern differs from Bhavnani & John [1997] in one major way. Our concern is with strategies that apply across sets of tasks, rather than with the 'low level' within-task strategies explored by Bhavnani & John [1997].

3 Derivation and Overview of the Task Grouping Strategies

Smith et al. [1997] provided several planning heuristics, two of which indicate that aspects of a set of tasks can be merged, either through the creation of composite objects that support multiple goals, or through grouping task elements by the commonality of task behaviours.

We also assume that people are capable of making groupings out of a set of tasks and we assume that the *context of task execution* has an impact on the forms of grouping that are made.

Informal evidence backs up the view that task groupings are in existence. A common example is a group of tasks whose main relationship is that they are all performed within, outside or near to a specific location. A specific example would be a person making themselves a refreshment, whist attending to 'personal needs', and picking up and dropping off their post. Another example are those people who batch

a number of instances of the same task and perform them together. Photocopying, printing, searching for references, reading research papers or dealing with emails are all examples of groupings that can be informally observed in everyday task performance.

If we extrapolate from TKS's concern with the sharing of attributes, features and functions, we can argue that groupings such as these may be represented as strategies whose concern is to relate tasks based on features. The two examples given previously suggest relationships based on locational, and class-instance features. The behaviours that remain goal directed, both in relation to the goals of each individual task and the goal behind the grouping strategy (e.g. save time, minimize interruption), but are non-obligatory in that the individual tasks will not fail if they are not followed.

3.1 Overview of the Case Studies

Sections 3.2 and 3.3 provide more overviews of the two studies relevant to this paper. This subsection is concerned with outlining the rationale behind the studies.

Our starting point for the studies was a general exploratory investigation into multiple task phenomena. Our main concern was to study real world task performers undertaking multiple tasks in the contexts of multiple; tasks, roles, tools, task-objects, and goals with the attendant facets of the world such as events, interruptions, breakdowns and exceptions. The studies were part of a more general investigation in multitasking. As such task groupings were not explicitly sought by the studies, they are based on evidence and inference from the studies. Within the studies our wish was to be able to focus upon the minute-by-minute detail of a task performer and trace the longer-term aspects of multiple tasks within a larger set of tasks or defined processes. Constraints on the research process surrounded having consent to video tape the subject in order to gain a record of minute by minute behaviour, and the willingness to talk about the longer term task performance. We were able to gain consent to generate video data with one person and consent for longer-term access with another.

When we consider the studies in the light of multiple task phenomena, the research question driving this paper is:

- Are there task-structuring mechanisms that govern how a person plans and interleaves the execution of a set of similar or dissimilar tasks in their environment?

  Corollaries to this question include:

  C1. When are such groupings used, what are the costs and benefits associated with them?

  C2. When a grouping is possible why is it not undertaken?

  C3. What further theoretical constructs are needed to provide explanatory accounts of the grouping strategies?

Grouping by	Example	Data source
Deadline	Two tasks with hard and soft deadlines were performed as soon as possible.	Task order, verbal statement.
Tool	Reading of emails, writing of emails.	Explicit actions with tools, verbal statement.
Location	A number of tasks that needed to be performed outside of the office were grouped together.	Explicit gathering tools and artefacts that met the pre-conditions of the group of tasks.
Participant	A number of tasks were grouped in relation to a specific participant, whose help was needed for all the tasks.	Verbal statement.
Role	The subject cleared time for one role (research) and allocated time in her diary to focus on another role (teaching).	Explicit planning and verbal statement.
Transformation	A number of documents were placed together to be photocopied at a later time. A notable exception to this was a document considered personal and private that was copied separately.	Verbal statement.

Table 1: Candidate groupings of tasks.

3.2 Pilot Case Study

The pilot study reported here is a detailed analysis of a video recording of an hour long slice of a researcher performing a number of tasks [Wild et al. 2003c]. The researcher's role was participant observer and where necessary conversed with the subject about relevant tasks. The main source of data was the video recording, however the participant observer also had relevant background knowledge. The analysis of the video recording started with the production of complete time annotated transcript. The next phase was to examine the physical actions which led to the addition of contextual information such as artefacts and tools used as well as locations and participants. A first pass attempt describes and defines the tasks that were planned, attempted and undertaken. In turn this was presented to the participant for feedback and criticism.

The participant in question was a researcher with additional teaching duties. A key motivation was to create a block of undisturbed time in order to focus on her own project's research analysis. Furthermore, as a new staff member, she faced questions along the lines of 'how do I?' and 'where is?' The participant had 6 main roles which generated attempts to plan and execute 17 distinct tasks during the observed period. The participant was the explicit recipient of 5 interruptions by other agents. She also interrupted her own task performance on 9 occasions and she interrupted other people 14 times. These interruptions and other events meant that task suspension and switching / interleaving was common. In terms of the wider environment the

Object	Attributes
UCAS day	(date, time, start, location, expected applicants [list], expected accompanying persons [list], day_schedule (tours), SV_timetable, APP_timetable, exceptional interviews).
Course Intake	(students, expected_grades | achieved_ grades, start dates, and course).

Table 2: Objects and attributes from the UCAS day study.

Task phase	Central tasks
Phase 1: Applicant Processing.	Central tasks include, logging, choosing and sending offers to applicants.
Phase 2: UCAS day planning.	(Central tasks include, picking dates, booking rooms and catering, notifying participants).
Phase 3: UCAS day execution.	Central tasks include, setting up the room, registering the applicants.
Phase 4: UCAS day follow up.	The central task being to inform the student of the admissions tutors.

Table 3: Tasks and task phases within the UCAS study.

participant interacted with 16 different participants (35 cumulatively). Over the hour, tasks and interactions took place in 8 different locations excluding traversed corridors.[3] Much of this data is interesting in its own right [Wild et al. 2003a,c], but from the perspective of this paper we were able to identify a number of candidate groupings of tasks, presented in Table 1.

3.3 Case Study Two

Our second study was a longer term study of the planning and execution of administrating undergraduate applications (commonly referred to as UCAS). One of the UCAS day sessions was observed, and this was combined with email and document analysis and a number of informal interviews. The interviews were undertaken to both understand the tasks, clarify our understanding of the tasks and to 'test' interim task representations.

The main participant in the study was a secretary whose three roles were, undergraduate and postgraduate admissions secretary, and being a member of the general office support team. Each of these roles had a different line manager.

The UCAS tasks can be seen as the creation of two types of abstract object described in Table 2, and can be divided into four phases described in Table 3.

As well as having several UCAS days there are multiple applicants. A single applicant is never dealt with within a single time period, due to natural breaks [Smith et al. 1997] in the task of processing a single applicant. Throughout the processing there was batching of a number of activities (e.g. logging applicants) relating to

[3]Other interesting features are reported elsewhere [Wild et al. 2003a,c], namely constant re-planning, switching and suspension of tasks, alternative execution strategies and the nature of the interruptions.

around 30 applicants at a time. Because there are multiple UCAS day instances and multiple applicants there are several instances being created at any one time. In theory each applicant could attend any one of the eight UCAS days. This potential for chaos, is reigned in by initially offering candidates two dates to choose from and then dealing with exceptions.

The UCAS process also has a number of immutable deadlines set by an outside agency. To enable reporting of activities with accuracy about progress, organizational and personal deadlines are set which provide further constraints on the tasks being performed.

Overall, the tasks for each specific UCAS day temporally overlap and elements interact. There are many interesting features within this case study that are reported elsewhere [Wild et al. 2003b], including the non-negotiated delegation of tasks, how events and instances relate, and the need to distinguish generic, instance and repeated tasks. And whilst much of this data is interesting in its own right what we highlight from this study within this paper are a number of observed task groupings and observations about them:

- Grouping by role. Throughout the process, tasks that could have been grouped by other criteria were overridden by the priority and deadlines generated from a specific role.
- Grouping by deadline. Of the weekly set of tasks that the administrative assistant was responsible for a number were grouped by the deadline they most related to.

Overall in this case, groupings of tasks occurred less often, and were less dynamically formed. Furthermore, reporting requirements such as the need to report to the manager on task progress and deadlines, such as the need to pass on batches of applicants on time, provide major shaping forces for the tasks carried out.

3.4 Interim Conclusions and Candidate Groupings

There are commonalities in the nature and findings of the two case studies. They both studied people with multiple roles and tasks, had some form of layering of goals that motivated general task performance above and beyond the immediate goal of the tasks in hand. There were also several task groupings observed.

From the two case studies four candidate grouping strategies are suggested:

- Grouping by deadline. For example when several urgent tasks must be completed before a specific time, regardless of whether there are any formal relationships between them.
- Grouping by location. For example when a number of tasks are grouped by the proximity of the locations they are carried out in.
- Grouping by participant. For example when a number of tasks are grouped by the need to involve another participant in their planning or performance.
- Grouping by role. Tasks that relate to a specific role are grouped.

It is important to note that grouping by tool and transformation was dropped from consideration because conceptually it was considered difficult to distinguish groupings from each other. Furthermore, grouping by tool appears too frequently and in too coarse grain a manner to be useful. Both studies suggest that groupings are not an all or nothing phenomena, sometimes groupings will occur, but it is as important to consider how aspects of context of a task performer affect whether they actually occur. In line with the view that strategies are non-obligatory [Bhavnani & John 1997], we suggest that within TKS modelling of multiple tasks, the use of strategies to represent task groupings captures their goal-directed and non-obligatory nature.

4 Discussion of the Candidate Task Grouping Strategies

Overall we have four candidates for grouping strategies: Grouping by deadline, location, participant, and role. This section discusses these grouping strategies in more detail, providing examples from our case studies, everyday life and emphasizes the costs and benefits for the application and non-application of the strategies.

4.1 Grouping by Deadline

Deadlines along with many temporal issues relevant to the modelling of tasks are neglected by HCI. To understand more about the implications of grouping by deadlines, it is important to consider deadlines in general.

A deadline is a temporal feature that implies some form of cut-off time or date to indicate the end of, or start of tasks. Deadlines can be seen as hard or soft [Lee 1999]. Hard deadlines may reflect physical properties of the task domain such as reaction times in chemical processes. Or they reflect constraints imposed socially / organizationally to impose order onto a task environment. Missing such hard deadlines will result in some form of task failure, in physically based processes this could be disastrous. In socially or organizationally oriented tasks this could be politically embarrassing, or result in legal / financial reprimands. Soft deadlines, are less likely to reflect physical constraints and reflect personal, social or organizational priorities and values. Deadlines are set in different ways. If they are set internally, by the person, group or organization, they relate more to the entity's overall motivation, priorities and values. When set by external bodies, deadlines are much more of a constraint in the environment that needs to be considered in the longer term planning and execution of tasks. Both sorts influence the planning and execution of tasks.

A benefit of deadlines is that their setting and attainment enables state monitoring — an important facet of project management. They also serve as a motivational factor in tasks. Another benefit is to stop an endless or open-ended task, in effect by saying that in this time slot we can only do so much. Deadlines also serve to demarcate the start of subsequent activities, setting a deadline for paper submission enables paper reviewing to start, and in turn setting a deadline for reviews to come back enables programme selection.

Instances of this grouping are present within the two case studies. In the pilot study the subject had two deadlines. One hard, the booking of AV and one soft, the passing on of information to a colleague that shaped the execution order of her set

of tasks. Within the UCAS case study there are numerous hard and soft deadlines. The hard deadlines are set externally by the UCAS organization and the university as a whole. These are in addition to softer deadlines set by the secretary in order to manage her time and be able to report to her manager the status of the task.

4.2 Grouping by Location

Location serves as one physical aspect of context, serving as both a 'container' for contexts, and as a factor in how tasks are grouped. At some level of description all tasks are undertaken in a location. Some locations are intrinsic to a task and its context, through the near permanent location of artefacts (desks, photocopiers, printers), work areas (wards, surgeries, meeting rooms), and social areas (e.g. reception area, private office, tea room).

Within the pilot study we saw a grouping of a number of tasks whose main grouping criteria is deemed to be those tasks that involve participants, resources, activities, that are located outside of the office. This was inferred from the implicit order of the tasks and from the gathering of tools and artefacts that were relevant to the grouping (e.g. diary task, to-do-list, security card). This form of grouping serves to save one resource, the repetitious movement of a person in their environment against other factors. Two key issues that are traded off by this grouping strategy are the costs of making alternative trips to the same location verses the availability of the resources needed for the set of tasks. In the former case, the benefit is the reduction in the number of journeys. In the latter case either the costs of setting up the grouping, or the costs of executing all the tasks in a given location, are higher than is considered acceptable. A third option is to plan the trips in relation to other tasks so that whilst the multiple journeys are made they provide a break to the main ongoing task.

In the second case study, the secretary will make multiple journeys to the same location in order to execute subtasks to meet soft deadlines. Whilst an alternative groupings of tasks could be undertaken, the overall groupings of tasks reflected roles and deadlines.

4.3 Grouping by Participant

The need to interact with another participant for a number of tasks can result in a grouping of tasks that involve that participant. There are two examples of this form of grouping within the two case studies. In the pilot one such grouping was planned, and is evidenced in explicit verbal statements, but not undertaken due to the absence of the participant. The UCAS days were planned and structured to bring together a number of different participants in different roles (applicants, parents, admissions tutor, UCAS administration assistant, lecturers, current and past students) together during the same time period. As such it can be seen as an pre-planned and refined grouping by participant.

In the first case the major trade off here is between the number of interruptions to the participant focused on in such a grouping strategy, against the costs incurred to the person making the grouping. It can be that interruption costs are minimized for both participants if this grouping strategy is used, rather than either participant going back and forth, all the tasks can be progressed within one meeting or exchange. However, the set up and execution costs of planning for a grouping such as this are

potentially higher. As well as the individual pre-conditions of each task the grouping may impose resource costs of its own. The interaction between participants can refer to different tasks. A mental note to do several tasks with a particular participant may be obscured by the fine detail of each task. Reminders such as to-do-lists, diaries etc., may help ameliorate this phenomena.

A common example, when a person has to talk to an administrator, they may group a number of tasks that relate to their role(s). This pattern can be formalized through regular meetings such as those between managers and personal assistants.

Meetings with multiple participants have refined conventions and structures that support and order interaction in relation to a set of tasks, an agenda serves as an example. In this second example a potential cost is that interaction may fragment into concern with tasks that may be a benefit for the group as a whole, reducing the cost effectiveness of the meeting's set up costs.

Artefacts such as email and voice mail messages, notes, and letters enable an alternative version of this grouping. One instance of these artefacts can serve to exchange information about a range of unrelated tasks in one message. Although the immediacy, pace and opportunism of such artefacts will be different.

4.4 Grouping by Role

TKS's role construct provides a modelling concept that maps between the tasks performed and the wider organizational context. Roles reflect commitments and task responsibilities in relation to the environment around the role holder. They entail issues such as reporting and supervision. As we move into contexts where multiple tasks are present, multiple roles are an obvious phenomena to account for. In both the pilot and the follow up study each participant had many roles. And in general role strain has been identified as a contemporary issue in HCI [Beyer & Holtzblatt 1998].

Within the case study we see several examples. In the pilot study the subject was observed explicitly allocating time to a teaching role, and as mentioned a motivation behind the tasks being formed was to clear time to focus exclusively on her research. Within the second case study the secretary's attention to roles helped to shape the ordering and execution of tasks.

With multiple roles it is likely that different roles will differ in priority. Tasks within a high priority role maybe grouped (e.g. research day), or placed in time periods when interruptions are minimized. This is an example seen within study one, with the researchers overall motivation is to create a block of time where little should impinge on the high priority task of research analysis. It can also affect the opportunity to undertake other grouping strategies through the generation of deadlines.

Roles may also have specific durations, for example chairing a conference. Roles may also be mutually exclusive. Two forms of mutual exclusion can be identified, the first is generic and applies to contexts such as legal representation. People maybe able to perform as a judge, defence, or prosecution but not all three. The second form is specific and would refer to how the roles of paper writer and reviewer cannot be held by the same person in reference to a specific paper written by them.

4.5 Breaking Down Task Groupings

Corollary 2 of the main research question was "When a grouping is possible, why is it not undertaken?" It is therefore important to consider factors in the environment that can unpick these groupings. Two interrelated factors in the environment seem to help prevent the utility of grouping tasks. These are deadlines, and reporting requirements.

The presence of deadlines can act to prevent groupings from being effective strategies. For example, it would be pointless to group a set of documents to photocopy for later in the week when two of the documents need to be sent off within hours.

Reporting requirements relate to the ability to report to other participants — especially managers — the status of tasks. The reason for the deadlines in case one was to enable a colleague to report more effectively in a meeting the following week. The issue of reporting requirements is most manifest in the UCAS study: There are three roles, three different managers and a host of information and tasks to track, coordinate, distribute, delegate and report on. The ability and willingness to report on the status of a task are important. In study two tasks are performed in manner that trades off the 'travel resource' against the definitive completion of tasks.

5 Implications For Task Knowledge Structures

Awareness of grouping strategies provides further primitives with which to understand the structure and context of work and are therefore something for TKS to model when being extended to cover multiple tasks.

When considering the implications for a theory driven approach like TKS, there are two relevant issues:

1. What current concepts within TKS needed highlighting or revising?
2. What further theoretical constructs are needed to provide explanatory accounts of grouping strategies?

With regards to the first question we focus on pre- and post-conditions and roles. Pre- and post-conditions are often represented in the goal hierarchy of TKS models of tasks. In the context of multiple tasks there is a need for greater explication of pre- and post-conditions, because groupings increase the salience that they take on. There is no longer just one set of pre- and post-conditions activated during task performance. There is now a set of pre-conditions for the individual tasks in the grouping plus any conditions that have to be met for the grouping to be successful. The need to construct and maintain this set in dynamic and ad-hoc contexts has mental resource implications.

The role construct in TKS, provides a modelling concept that maps between the tasks performed and the wider organizational context[4]. Roles reflect commitments and task responsibilities in relation to the environment around the role holder. GTA [van der Veer et al. 1996] introduced the agent concept and is a useful addition to

[4]Its influence can be seen in similar constructs being included in GTA [van der Veer et al. 1996] and Contextual Design [Beyer & Holtzblatt 1998].

the modelling of tasks However, the notions of agency and interaction with roles are issues that need deeper consideration before being adopted within HCI. Sometimes participants will interact according to roles and sometimes by the specific agent. It is likely that this will affect what groupings of tasks are considered appropriate.

When we consider the extension of TKS, one of the main considerations for TKS is the notion of competing and overlapping goals. It is clear that just as knowledge exists at different levels, goals exist at a number of levels. Goals can differ in how abstract-concrete, general-specific or high-low level they might be. For example, when looking for a very recent and relevant journal paper that can be accessed via the Web, several goals might simultaneously be active. One goal might be to become familiar with searching the Web in general, and for journal papers in particular. Another goal could be to cause a co-author surprise in how up-to-date one is with relevant journal articles. Another goal is to contribute to the joint paper that is being written. Yet a further goal might be to receive the information before lunchtime and without trekking in the rain to the library. All of these goals are different, either in terms of their generality or specificity, some have social implications and contribute to joint work, others relate to resource limitations.

Goals can be classified as compatible or incompatible. Compatible goals can be pursued in parallel. Incompatible goals cannot be pursued in parallel but would involve some form of interleaving. Goals at different levels of abstraction can occur in parallel and are therefore another kind of compatible goal.

In general we recommend that during the analysis of the task domain and task performers the elicitation of priorities and values, role complements and conflicts is made more prominent when we consider how tasks relate to each other. This should shed insight into what the higher level goals a person has when they approach a set of tasks, potentially leading to grounded qualitative predictions about what grouping strategies they use in the planning and executing of tasks.

When we consider deadlines, we note that TKS has a rich set of temporal operators for describing and scoping the temporal relationships between subgoals [Markopoulos et al. 1997]. But as it stands TKS models represent time in a relative sense. They are not embedded in time as experience by people, whether subjectively or culturally. Deadlines are seen to be a shaping force, both within this paper and elsewhere [Lee 1999] and other temporal issues such as natural breaks need to be accounted for in the extended version of TKS.

When we consider TKS and location we note that location has been used implicitly in the use of scenarios. However locational issues need to be highlighted when modelling tasks. Our work shows that location can be used explicitly in the planning and ordering of tasks. Whilst this may be appropriate in designing support for say, planning tools, deeper insights from how people use locations, space and place [e.g. Harrison & Dourish 1996] will inform future developments within TKS.

5.1 Reflecting or Shaping the Environment: Context vs. Categories

In HCI the environment is often an ill defined notion. We see broad appeals to notions of situation or context, but little systematic attempts to elucidate what this means. Those that attempt to scope the discipline and environment of HCI [e.g. Dowell & Long 1998], are criticized for missing vital social elements of the task environment

[Green 1998]. In the discussion so far, we have noted that as well as the traditional elements on a TKS of a task (e.g. roles, goals, task-objects, actions) there are other facets of context that we need to consider in greater detail (i.e. deadlines, locations, and participants). However, we cannot provide a simplistic listing of these factors in an extended TKS approach. Some work in situations and context sets the scene for aspects of context [e.g. Harrison & Dourish 1996; Lee 1999], but does not contain any detailed notion of tasks and their structure. In other approaches tasks are reduced to some form of simplistic process model or as opportunistic reaction to complexity of environments. Whilst it may be possible to elucidate a model of context that is both broad and useful, subtle issues arise. One question that can be framed is whether an entity or property is part of the environment that a task is executed in, or part of the conceptual representation that drives a task. Palmer [1978] talks of representing worlds, such as the knowledge we hold in the mind and represented worlds, that is the environment that is being represented. Both the representing and represented worlds are dynamic and the interplay between them is one source of the complexity of cognition. For example sometimes an environmental factor (e.g. location) is a resource, used and traded of against other resources, sometimes a key facet of the task, and sometimes it is just an necessary, but unused aspect of context. Overall, as humans we are as much imposing a structure onto the environment as having to reflect the environment in our conceptual representations of the world. Strategies such as those presented within this paper are an example of the way this interplay between representing and represented worlds occurs.

5.2 Resources, Costs and Task Qualities

Colloquially resources refer to the means that are used when doing something. Resources are important because they are expended and conserved by people performing tasks. With reference to quality we are all familiar with management never ending quests for ISO quality. Quality, can also relate to many contemporary aspects of cognitive, social and organizational structures. More specifically within HCI we see the traditional measures of quality such as ease of learning, low number of errors and with growing interest in the quality of user experience [Preece et al. 2002].

Such notions are often used explicitly [Smith et al. 1997; Wright et al. 2000] and implicitly [Preece et al. 2002] in the literature. To date little work has attempted to elucidate resources, costs and task quality. Our discussion in Section 4 made informal reference to resources. But if task grouping strategies are non-obligatory and composed and chosen in relation to the costs and benefits, more precise use of the terms needs to be made. We are now working towards a characterization of such issues. This attempts to list common resources and task quality measures; their properties and how they relate to tasks in general, groupings in multiple tasks, and the collaborative aspects of task performance.

6 Conclusions and Future Work

We began with the observation that there is little support for multitasking, and observing that task groupings are both possible, desirable, and occur. We reported an

interim analysis of two case studies that provide further evidence that groupings of tasks occur. These groupings have functional value in ensuring acceptable levels of task quality and recourse utilization, but are not essential. Rather they are strategies that are focused around the use of context in a broader sense than TKS has considered in the past.

We are keenly aware that grouping strategies are a small part of the multiple task phenomena [Wild et al. 2003a,b,c]. Included for consideration in wider discourse should be issues such as interruptions, suspension of tasks and participating in task performances with others. Nevertheless task groupings occur and have salience, being evidenced within our studies, everyday life and other HCI frameworks [Smith et al. 1997].

As we move away from examining the structure of single tasks we move into an area where, because of non-obligatory goals, tracing both the existence and implications of task groupings are difficult. It is important to be able to form explanatory accounts that are not bound to simple or surface factors of context. For example, all tasks occur in a location and in theory we could claim that everything we do is grouping by location. Similarly collaborative and cooperative activities will always involve participants. We caution against over-zealous use of the concept of grouping strategy.

With all this in mind, our current work centres around several issues. The first is further observation of these and related multiple task phenomena. The second is providing deeper explanatory accounts of the phenomena from the case studies to enable the development of something more than yet another set of design heuristics about groupings. We are also undertaking design efforts as a way, of gaining further insight. Prototype development of an interactive system that supports a number of these grouping phenomena and others (constant re-planning, interruptions, multiple execution choices, switching and suspension of tasks) is being undertaken. Feedback from these efforts will provide further insight into the way people multitask. It has also been suggested that the time management literature [Hall & Hursch 1982] may provide further insights and explanations about task ordering and grouping. And this will compose another strand in our future work.

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